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Social-ecological resilience and socio-technical transitions: critical issues for sustainability governance

Adrian Smith and Andy Stirling

Transitions

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Technology contributes both positively and negatively to the resilience of 'social-ecological systems', but is not considered in depth in that literature. A technology-focused literature on socio-technical transitions shares some of the complex adaptive systems sensibilities of social-ecological systems research. It is considered by others to provide a bridging opportunity to share lessons concerning the governance of both. We contend that lessons must not be restricted to advocacy of flexible, learning-oriented approaches, but must also be open to the critical challenges that confront these approaches. Here, we focus on the critical lessons arising from reactions to a 'transition management' approach to governing transitions to sustainable socio-technical regimes. Moreover, we suggest it is important to bear in mind the different problems each literature addresses, and be cautious about transposing lessons between the two. Nevertheless, questions for transition management about who governs, whose system framings count, and whose sustainability gets prioritised are pertinent to social-ecological systems research. They suggest an agenda that explores critically the kinds of resilience that are helpful or unhelpful, and for whom, and with what social purposes in mind.

About the Authors

Adrian Smith / SPRU Senior Research Fellow. Adrian specialises in critical analysis of environmental policy processes and research into relationships between technology, society and sustainable development.

Andy Stirling / STEPS Co-director, SPRU Science Director and Professorial Fellow. Andy trained in archaeology and anthropology, later working for Greenpeace International before researching technology policy. He now works on the governance of science and innovation.

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For further information please contact: STEPS Centre, University of Sussex, Brighton BN1 9RE
Tel: +44 (0) 1273606261
Email: steps-centre@ids.ac.uk
Web: www.steps-centre.org

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ABSTRACT

Technology contributes both positively and negatively to the resilience of 'social-ecological systems', but is not considered in depth in that literature. A technology-focused literature on socio-technical transitions shares some of the complex adaptive systems sensibilities of social-ecological systems research. It is considered by others to provide a bridging opportunity to share lessons concerning the governance of both. We contend that lessons must not be restricted to advocacy of flexible, learning-oriented approaches, but must also be open to the critical challenges that confront these approaches. Here, we focus on the critical lessons arising from reactions to a 'transition management' approach to governing transitions to sustainable socio-technical regimes. Moreover, we suggest it is important to bear in mind the different problems each literature addresses, and be cautious about transposing lessons between the two. Nevertheless, questions for transition management about who governs, whose system framings count, and whose sustainability gets prioritised *are* pertinent to social-ecological systems research. They suggest an agenda that explores critically the kinds of resilience that are helpful or unhelpful, and for whom, and with what social purposes in mind.

INTRODUCTION

Scholars of social-ecological systems recognise technology as an important influence on resilience (e.g. Langridge et al, 2006; Young et al, 2006; Anderies *et al*, 2004). With a number of contrasting relevant definitions of 'resilience' (Berkes *et al*, 2003; Stirling, 2008a), this influence may alternatively be positive or negative, depending on the context. Indeed, even under any single given perspective, there are technologies that undermine this quality and those that have the potential to enhance it. However, the social-ecological systems literature rarely considers the dynamics of technological change in any detail. A parallel literature that focuses on transitions towards more sustainable socio-*technical* systems does consider the dynamics of sustainable technological change in some depth (Rip and Kemp, 1998; Rotmans *et al*, 2001; Smith *et al*, 2005).

A number of scholars have noted how these two literatures conceptualise their objects of study in similar ways (van de Brugge *et al*, 2007; Foxon *et al*, 2008). Social-ecological systems and socio-technical systems are each understood to display complex, multi-scale and adaptive properties; and the associated recommendations for the sustainable governance of these systems emphasises approaches based on learning, experimentation and iteration. Such similarities are encouraging dialogues between the two literatures (e.g. Voss *et al*, 2008). There are strong parallels between the challenges faced in social-ecological and socio-technical systems research.

At present, dialogue has been limited to a fairly uncritical comparison of the favoured governance strategies: adaptive governance for improving the resilience of social-ecological systems, and transition management for promoting sustainable socio-technical systems (van de Brugge *et al*, 2007; Foxon *et al*, 2008). One purpose for our paper is thus to argue that constructively critical challenges between approaches must also be part of the lesson sharing process. Given our technology focus, we consider critical challenges to transition management and suggest implications for governing social-ecological system resilience.

However, when seeking to transfer lessons across the literatures, it is important to bear in mind their relevant idiosyncrasies and contrasts. It is a feature of complex, adaptive systems that 'the devil is in the detail'. In either area, properties of dynamic open complex systems – like resilience – can be parameterised in different ways (Stirling, forthcoming). These parameterisations may in turn each be associated with divergent normative frameworks. Crucially, the focus of socio-technical transitions research, the ways it frames problems, and its intellectual roots are different to social-ecological systems research. It is important to retain a critical awareness of the many contrasts and tensions between the two kinds of system. Indeed, under any given view, properties considered desirable in socio-technical terms might actually cause problems in social-ecological systems terms. Transitions to sustainable socio-technical systems may thus not automatically furnish resilience across social-ecological systems. Given this, the second purpose of our paper is to explore some of these differences and consider what they mean for future dialogue.

The paper is organised as follows. The following section considers the significant mediating roles technology plays in social-ecological systems. A way of thinking about technology as 'socio-technical configurations that work' is introduced in the following section. These ideas have been adapted into a proactive form of 'transition management' aimed at the radical and sustainable transformation of socio-technical systems, which is covered in the following section. Favourable comparisons in the literature between these governance prescriptions and the adaptive governance of socio-tecological systems are considered before moving on

to the critical challenges confronting the transition management approach. These different challenges are interpreted as deriving from a more fundamental question of power and agency. The relevance of this for social-ecological systems governance is addressed in the penultimate section of the paper, before summarising and concluding the arguments in this paper. We suggest that, rather than developing ever more idealised notions of governance, insights from the socio-technical transitions perspective be used in a more engaged way with the politics of sustainable development that already exists.

TECHNOLOGY IN SOCIAL-ECOLOGICAL SYSTEMS

All technologies rely on the natural world to furnish raw materials, provide energy, and assimilate wastes.[1] Technologies help us monitor and understand our impacts on the natural world: they have profound mediating affects in social-ecological systems. In a review paper, Berkhout and Gouldson (2003) identify technologies as playing four roles in relation to ecosystems:

- There are technologies that provide sensors and information concerning the states of ecological systems. This includes technologies like satellite imaging of land use operating at the macro-scale, or the mass spectrometry of soil contamination operating at the micro-scale. Significantly, each monitoring technology facilitates an appreciation of social-ecological systems in certain ways, and not others, and it is the ways in which these representations are articulated into knowledge that structure our overall understandings of social-ecological systems.[2]

- Technological change stimulates economic growth and re-structurings of social development that impact upon multiple social-ecological systems. Mass aviation systems and information and communication technologies are two important fields of technology that have facilitated globalising economic patterns, for example, with all the mixed ecological and social consequences associated with such economic trends. More specific socio-technical developments, such as the mutually reinforcing growth in factory fishing and fish consumption, can bring more localised pressures to bear on certain social-ecological systems.

- Cleaner technology improves the efficiency with which material resources are harvested and transformed into valued outputs. This includes both production technologies (such as electricity generation from renewable sources) and consumer technologies (such as more energy efficient household goods and services). It also includes recycling technologies, which seek to close the loop between production and consumption, and pollution control technologies.

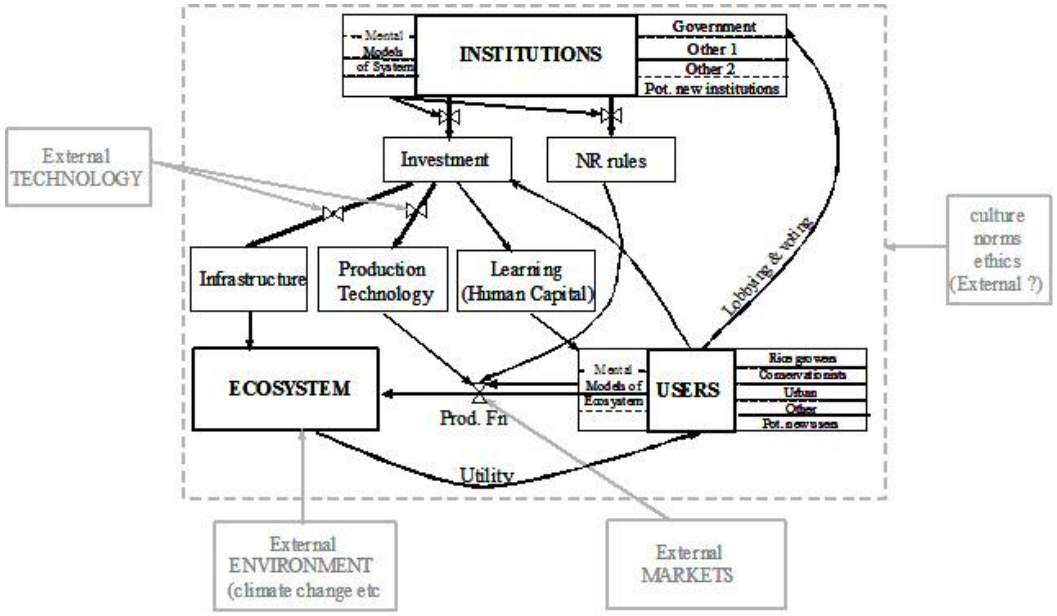
- Finally, technologies are being developed with the specific aim of repairing the environmental impacts of existing (technologically-mediated) activities. Examples

[1] The term 'social-ecological system' used in this paper extends beyond ecosystem services to include technological use of natural resources (e.g. minerals).
[2] Although development of these technologies was informed by monitoring goals emerging out of prior understandings and assumptions, the monitoring techniques developed to meet those goals may subsequently shift prior understandings (eg: through enhancements in cognition).

here include the application of biotechnology to remediation of contaminated sites and the innovation of agricultural techniques to restore biodiversity.

- The influence of technology in social-ecological systems is well recognised in the literature. Figure 1 reproduces a schematic representation of a social-ecological system taken from the Resilience Alliance website, adapted from Anderies *et al* (2004). Technology mediates relationships between key elements of the system (underlined in the diagram). Institutions co-ordinate investments in infrastructure and production technologies, with consequent influences on ecosystems. Technology choices affect the production function that influences relations between users and the ecosystem. In turn, governance strategies for promoting greater social-ecological systems resilience must consider technology choice, its patterns of use, and its control.

Figure 1: the exogenous driver and endogenous mediating roles of technology in social-ecological systems



Source: http://www.resalliance.org/563.php (accessed 25/1/2008).
RA present this as their 'most recent conceptualisation' of a social-ecological system.

Understandably given the focus on what is already a wide-ranging and complex social-ecological system, Figure 1 conceptualises technology as exogenous. Processes that shape and select the array of available technologies are seen to operate outside the social-ecological system. Technology development is thus somewhat out of focus. Nevertheless (as argued above), the dynamics of technology development and use do carry implications for focal concerns over the resilience of social-ecological systems. It will be discussed in the following sections, how technology development and use can themselves be understood as embedded within (and embodying) wider complex adaptive systems. It is this view that prompts some to explore the potential for dialogue and synthesis.

TECHNOLOGY AS SOCIO-TECHNICAL SYSTEM

Scholars and policy-makers interested in sustainable technologies find the socio-technical systems perspective attractive for two reasons. The first is that the widespread creation and diffusion of cleaner technologies is predicated on facilitating changes in broader social, economic and political systems. The second reason arises from recognition that some environmental goals (such as drastic reduction in carbon emissions) cannot be achieved through individual cleaner technologies alone (e.g. renewable energy), but instead require structural changes to encompassing socio-technical systems (e.g. energy infrastructures).

Any focus on technology requires caution over slippages into technological determinism. Of course, technologies exert impacts on the societies in which they emerge. Conversely, discursive and material commitments in society help shape technology design. Both recursive forms of influence can be highly uncertain – and thus contrary to intentions. A long tradition of research in history, philosophy, sociology and evolutionary economics explores the social processes underpinning development and use of artefacts. As new technologies become domesticated in everyday lives, they can constrain and enable in important ways. But these structuring qualities may reflect prior social relations, and/or initially be indeterminate in their impacts. Historians of technology use the term soft determinism to express this co-evolutionary process of mutual structuration (Nye, 2006).

Social processes shape development and use of technology; but artefacts in turn open up possibilities for new social practices (Russell and Williams, 2002). The development of electricity systems based on fossil-fuels has, for example, been shaped by the institutions developed to facilitate the operation and expansion of these systems, and led to a reinforcing development of a great variety of electricity-using goods and services. This may effectively exclude from certain patterns of development, those without access to a new technology (such as electricity-based goods and services for those beyond the grid). Socio-technical systems, like electricity, come to fulfil socially valued functions. But they also condition the ways these functions are conceived, by defining possible or desirable ends as well as the choice of means. A socio-technical systems perspective allows us to understand technology development and use in terms of the complex adaptive processes constituting the interdependencies between the material and the social.

New technologies never appear fully formed and in obvious working order (Bijker, 1997). Delivery of valued goods and services requires active development, linking and alignment of heterogeneous (social and technical) elements into working configurations. For instance, institutions are required to train engineers and provide facilities for developing particular styles of technology. These must in turn be linked to institutionally-structured market incentives, marketing possibilities and the specific needs of prospective consumers. Beyond this, broader social, demographic and ideological processes are at work. These include the cultural *milieu* in which the technology operates, where social movements, lifestyle expectations, environmental stresses and resource supply shocks can all exercise important influences on patterns of technology development and use. These processes (operating beyond, but interconnected with, specific technologies) are referred to as the 'socio-technical landscape' (Rip and Kemp, 1998).

A socio-technical systems perspective prompts researchers to grapple with this complexity. This always situates technology in the contexts that enable it to work. Hence the focal concern is not just with artefacts, but the structures, agents and processes that reproduce a 'socio-technical practice' (Rip and Kemp, 1998). This might refer, for instance, to the multiple materials, routines, institutions, actors and networks that provide us with automobility,

housing, food or energy services. Some socio-technical systems are embedded more robustly than others, in the sense that they enjoy greater institutional support, larger economic significance, more supportive infrastructures, better integration with other social practices, and broader political legitimacy. These strongly embedded, self-reinforcing systems are referred to as 'socio-technical regimes' (Rip and Kemp, 1998). Here, guiding principles, component technologies, user relations, industrial structures, policy frameworks, knowledge bases and institutional cultures are more established, interlinked and clearly aligned (Geels, 2002).[3]

Like other potential configurations, more sustainable socio-technical practices are at a distinct structural disadvantage compared to those practices already constituting incumbent regimes. Due to the as-yet unformed alignments, they are less economically attractive and politically weaker. The aim of transition research is to understand how sustainable regimes might become established over time. This also involves studying how incumbent regimes become unsettled and displaced by alternatives.

With something as complex as a socio-technical regime, contexts and pathways for change will vary from case to case. Various heuristics and typologies organise cases into broader patterns of change (Smith *et al*, 2005; Geels and Schot, 2007). These relate to the degree of conscious coordination, pressures for change, the origins of alternatives, and the sequence and nature of interactions between incumbent regimes, nascent alternatives and broader developments. In the context of sustainability, it is the possibility of accelerating transitions away from unsustainable regimes and along more sustainable pathways that preoccupies analysts and policy-makers. Here a particular mode of 'purposive transition' or 'transition management' is debated (Kemp *et al*, 1998; Rotmans *et al*, 2001; Smith *et al*, 2005; Loorbach, 2007).

TRANSITION MANAGEMENT

Transition management is concerned with how to govern transitions to more sustainable socio-technical systems. Here, it is important to recognise how past technological transformations tended to emerge from complex interactions between contending

[3] Here we must note some ambiguity and confusion in the literature regarding the terms socio-technical system and socio-technical regime. Our usage is to evoke socio-technical system to refer to working socio-technical configurations generally, including regimes; but to reserve the term socio-technical regime for those configurations that are more structured. In a thoughtful review, Markard and Truffer (2008) noted a tension between institutional understandings of socio-technical regimes, which consider them as a rule set or grammar (Geels, 2004), and more material understandings that include the actors and artefacts whose practices develop the rule set (Verbong and Geels, 2007). Geels (2004) has suggested actors reproduce and draw upon the regime rules within a wider socio-technical system that includes material artefacts and resources. In our view, we find it difficult to conceive a pattern of material socio-technical practices reproducing without the presence of institutions, just as it is difficult to see how institutions can develop without their re-enactment through networks of actors and artefacts engaged in socio-technical practices (Smith *et al.*, 2005). Indeed, to the extent that technologies embody the institutional contexts that produced them in enduring ways, technologies can make institutional changes – new rules – difficult to put in place. This materiality is a useful aspect of the structuring qualities to the regime concept, and we therefore include artefacts within our understanding of socio-technical regimes.

intentions, determinacies and contingencies. None were directed by shared, explicit, socially-deliberated, long-term goals like those presently associated with sustainability (Berkhout *et al*, 2005). Nevertheless, a limited number of historic studies have traced the emergence of new regimes back to originating niches (e.g. Geels, 2005). These have inspired ideas informing more ambitious purposive, sustainability transitions. Governance prescriptions in transition management focus on facilitating evolution out of such niches, especially where incumbent socio-technical regimes are under pressure to change.

Niches provide important settings that are less susceptible to prevailing market pressures. Expectations of performance are relatively independent from conventional criteria. Radical sustainable innovations that carry systemic implications typically need this kind of space to develop, improve and enrol support (Kemp *et al*, 1998; Smith, 2007). Consequently, transition management focuses on nurturing strategically-designed experimental niche settings, where: teething troubles are tolerated; new ways of doing things are valued; learning is encouraged and embedded in future development. Crucially, there is a coupling with supportive institutions to further develop the more promising nascent socio-technical practices by facilitating wider and deeper alignments (Hoogma *et al*, 2002). Finally, transition management recognises this facilitation includes processes to further unsettle and displace the incumbent regimes deemed problematic (Rotmans *et al*, 2001).

Transition management puts this niche-based, evolutionary view of change within an iterative, four-stage cyclical governance framework (Rotmans *et al*, 2001; Kemp *et al*, 2007; Loorbach, 2007). Advocates suggest much greater interaction than the sequence presented below, which for the purposes of introduction appears more linear than intended.

1. Problem structuring and goal envisioning

This is the starting point for transition management. Multi-stakeholder forums are convened, usually facilitated by a government department. Participants deliberate over the problems associated with the existing socio-technical regime. They debate the options for fulfilling the long-term goals that transition initiatives must serve. Long-term goals typically derive from formal public policy in the form of, say, carbon emission reductions, or air quality targets, or poverty reduction ambitions (Kemp and Loorbach, 2006). Great emphasis is placed on mutual learning, consensus building and developing a shared problem perception in relation to the goals (van de Brugge *et al*, 2007). Techniques such as scenario-building are used in developing the sustainable goals into socio-technical visions (Sondeijker, 2006). Visions are always provisional and open to revision, but they need to provide a promising solution to the goal. Visions have to perform a political function in the sense that they have to mobilise support and enrol resources for the subsequent phases of the transition management governance cycle.

2. Transition pathways and experiments

With the sustainable socio-technical visions providing a sense of direction, participants deliberate over potential pathways towards those visions. These deliberations remain quite inclusive, but tend to be more focused on specific sectors (such as energy), domains of practice (such as mobility), or locations (such as cities) (Loorbach, 2007). Back-casting methods are amongst the techniques used for prioritising pathways (Quist, 2007). This identification of transition pathways provides a framework for the subsequent development and support of alternative socio-technical practices in strategic niche experiments. A portfolio of niches is created, spanning different possibilities for early steps along one or

more potential pathways. Promoting diffusion and development in niches follows a pattern of initial 'pre-development', followed by a period of 'take-off' and 'acceleration', before culminating in 'stabilisation' within a more environmentally benign regime (Rotmans *et al*, 2001). Some experimental niches will fail and support be withdrawn. Coordination and linkages between niches are also considered important in the governance process. Transition management thus involves continual development of new niches, in an evolving portfolio of wider activities. Path-dependencies between niches are crucial; as are parallel interactions. Unanticipated consequences are inevitable – indeed intrinsic to the experimental approach. Outcomes are thus emergent, underscoring the stress on adaptive governance.

3. Learning and adaptation

Processes of learning and adaptation provide the essential links between long-term goals, socio-technical pathways and short-term actions in niche experiments. Lessons are drawn not just for instrumental improvement of the niche practices themselves, but also at higher levels concerning required revisions in the framing of associated policies, marketing, user relations, across the entire socio-technical configuration (Hoogma *et al*, 2002). Processes of engagement in niche experiments are also subject to scrutiny and appraisal (Rotmans *et al*, 2001). Given the long-term ambitions driving niche management, it is vital that experiments consider where future developments may lead, and what can realistically be expected from continued support. Second-order learning re-considers the motivating visions as 'wider processes, understandings, knowledges and values evolve' (Walker and Shove, 2007: 220). Niches also inform institutional reconfigurations, since one of the outcomes intended from this experimentation is to understand better the institutional constraints and opportunities for the alternative socio-techncical practices at the heart of the experiments.

4. Institutionalisation

This element is considered least in the transition management literature, though it is acknowledged to be the most important, since it overarches all the other activities (Berkhout *et al*, 2005; Kemp *et al*, 2007). Politically and economically it is the most difficult. Institutionalising emerging, sustainable socio-technical practices typically requires demanding policy reform, infrastructure investment, market restructuring, citizen mobilisation and changed consumer behaviour. This is the point at which serious commitments are needed, to such an extent that the incumbent regime suffers and is undermined as a result (Smith *et al*, 2005; Shove and Walker, 2007). Clearly, there will be losers as well as winners – with crucial asymmetries between those who know they will lose and those who hope they may gain (Machiavelli, 1532[1990])! This is the acid test for transition management. It involves the mobilisation of serious selection pressures against the incumbent regime, and redirecting vast institutional, economic and political commitments along alternative, more sustainable pathways. The latter involves politically contentious evaluations of the outcomes of experiments, and selections between promising niches.

To summarise, transition management injects goal-directing processes into socio-technical transformations. There are multiple governance challenges: collectively envisioning viable sustainability goals; nurturing promising niches; building supportive constituencies of actors, institutions and markets; and continually anticipating, learning and adapting. Proponents summarise transition management as 'goal-oriented modulation' of the dynamics of socio-technical change (Kemp *et al*, 2007). This is 'a constant process in which further adjustments

are made as environmental conditions change, these changes being, in part, the outcome of previous interventions. Feedback, monitoring and circuits of action and reaction are integral to this overall scheme' (Walker and Shove, 2007: 219).

This forward-looking literature shades readily into advocacy (e.g. Kemp *et al*, 2007). Key proponents consider themselves associated with a new, engaged way of doing 'sustainability science' for societal problems requiring structural changes in socio-technical systems (Loorbach, 2007). With a transitions approach becoming instituted in Dutch environmental policy (VROM, 2001) and of increasing interest elsewhere (e.g. NESTA, 2008, von Schomberg, 2002), the stakes are correspondingly raised. Some researchers advocating transition management ideas are involved in this policy development; indeed, important ideas have developed through this practical engagement (Smith and Kern, 2007). There is debate over the extent to which actual transitions policy in the Netherlands accords with the ideals of transition management (Kern and Smith, 2008). As discussed below, the power relations in existing socio-technical regimes, and the pragmatic compromises required in political processes, convey instructive lessons for debates about transition management and adaptive governance (see later).

COMPARISONS WITH THE GOVERNANCE OF SOCIAL-ECOLOGICAL SYSTEMS

As a governance approach, transition management of socio-technical systems shares some family resemblances with adaptive management of social-ecological systems. Van de Brugge *et al* (2007) point out a number of commonalities rooted in the 'shift away from equilibrium thinking into the complex, adaptive, and unpredictable behaviour' (p.2). They note a shared basis in systemic understandings in: learning-oriented approaches in the face of inherent uncertainties; acknowledgement of social complexities; an appreciation of dynamic, multi-scale interactions; and a common interest in self-organising sources of stability. These foundational similarities 'hold promise for cross-pollination' (ibid, p.3; also, Voss and Kemp, 2006).

However, the comparative work of van de Brugge and colleagues is fairly one-way. They introduce the transition management approach, much as we do above, and then discuss what advances it might offer for scholars of adaptive management. These promises include the way a multi-level perspective on transitions – recognising interactions across niches, regimes and landscape processes – informs the organisation of strategic, tactical and operational governance activities. They suggest the multi-stakeholder transition arenas that form a focus for co-ordination and advocacy could prove instructive for the 'shadow networks' in adaptive management, and anticipate these eventually influencing or even displacing older management institutions (Olsson *et al*, 2006). Both operate outside everyday decision processes, and form a vanguard for the new governance approach.

Foxon *et al* (2008) provide more of a two-way comparison. They introduce both the transition management approach and the adaptive management approach. A comparison is made between the two in terms of governance and management styles, scale of analysis and operation, information management and communication, infrastructure, and risk management (p.9). This reveals many generic similarities, including the prevalence of evolutionary, path-dependent change in both systems, and the flexible and learning-oriented approaches for modulating those changes. Foxon *et al* also note how both approaches value

diversity as providing an important capacity for promoting resilience. In the case of socio-technical systems, this diversity derives from the variety and disparity of niche alternatives (Stirling, 2007).

A key strength in Foxon *et al*'s contribution is consideration for the different emphases of these respective literatures. Adaptive management is more concerned with resilience that maintains social-ecological system functions and avoids large-scale collapse; whilst transition management is concerned with transformation to a sustainable socio-technical system over the longer-term. Adaptive management seeks an accretion of capacity in order to manage rather than direct change. Transition management is concerned with accelerating niche growth processes in sustainable directions. Foxon *et al* suggest this interest in directionality is something adaptive management might consider more fully. On the other hand, the more open-ended approaches to stakeholder engagement developed for building resilience in adaptive management are techniques that transition management could consider more fully.

Helpful as this is, a limitation of the dialogue thus far (taken as a whole), is a slight lack of critical reflection. Positive comparisons are emphasised, predicated on favourable views of transition management and adaptive management, and focusing on instrumental improvements. Little attention is given to critiquing either literature. Attention is thus neglected to how responses to criticism in one literature might contribute to the other.

CRITICAL CHALLENGES FOR TRANSITION MANAGEMENT

Given the scale of the sustainability challenges it seeks to confront, transition management holds strong instrumental ambitions for governance. Though accommodating divergences of emphasis, this presupposes a deep level of normative consensus. In practice, however, different socio-political constituencies take strongly divergent positions over the merits and drawbacks of different socio-technical practices – even where these are thought of equally as 'sustainable'. Contending perspectives frame socio-technical 'systems' in incommensurable ways, typically holding opposing views on options, priorities, benefits and impacts - and thus on the orientation of desirable transition pathways for sustainability.

The cleavage between 'hard' and 'soft' energy paths is a long-standing illustration (Lovins, 1976). It is reflected in current debates over the facility with which carbon capture and storage ambitions can realistically push coal-based electricity regimes along low carbon development pathways; or whether more decentralised and diverse electricity systems based in renewable energy sources are a more credible and desirable route. The challenge to each is different. One seeks its solutions in reforming a powerfully entrenched, yet problematically challenged, electricity regime. The other seeks solutions a radically different regime that is only weakly institutionalised. These disagreements and arguments provide ample tactical opportunities for the structural power of incumbent socio-technical regimes to mould discourse and channel influence: thus conditioning social agency in choosing between alternatives. These crucial political dynamics challenge straightforward 'managerial' understandings of transition management and sustainability governance (Smith et al, 2005; Smith and Stirling, 2007).

In this section we consider a number of difficulties that flow from this: Who governs? Whose system counts? Whose sustainability gets prioritised? How to articulate power and agency in socio-technical regimes? What is the political geography of transitions?

Who governs?

An obvious initial question concerns the locus of transition-governing activities and who is involved (Shove and Walker, 2007)? One of the features of the socio-technical perspective is that it cuts across policy sectors, implyng that multiple government agencies, institutions and associated policy networks will be involved. A state actor may be the facilitating agent, but transition initiatives may also be initiated within business communities or civil society (Kemp and Rotmans, 2005).

In terms of participation, transition management advocates argue that this should initially comprise 'visionary forerunners'. Such individuals are seen as empathetic to sustainability goals, open-minded, able to convey the 'transition vision' back to their constituency and influence its behaviour, and willing to put time, energy and resources into the governance challenge (Kemp and Rotmans, 2005). 'Transition arenas' thus build a network of change agents committed to instituting their shared sustainability visions, pathways, and experiments. The transition arena is conceived 'in addition to (partly independent from) the normal policy-making networks dominated by incumbent companies having an interest in the status quo' (Kemp and Rotmans, 2005: 146).

This practical conceptualisation sees transition governance as a vanguard sitting apart from incumbent socio-technical institutions and practices, but which seeks to intervene and engage them towards change (Smith and Stirling, 2007). Critics interpret this as a technocratic mode of governance (Hendriks, 2008). By this means, deliberations over structural transformations of socio-technical regimes affecting the lives of millions of people are led by a group of elite visionary forerunners.

The significance of links to democratic politics has been highlighted here (Hendriks, 2008). Whilst transition management sees sustainability goals deriving from conventional public policy arenas, and associated institutions for democratic and accountable oversight, it is unclear how involved are these institutions in the development of visions and pathways for realising those goals. Transition policy in the Netherlands is subject to parliamentary oversight, but there are questions as to whether this offers sufficient accountability and whether institutions of representative democracy should become more directing towards the content of the visions and experiments being followed. However, the long term, specialist deliberations involved in transition management can be difficult for parliaments to engage with (Meadowcroft, 2005). This prompts some analysts to consider other sources of democratic legitimacy, such as those prevalent in debates about networked governance (Hendriks, 2008).

Transition management has only been considered at the national and sub-national levels. It has tended to operate within the confines of specific political jurisdictions. However, many of the processes contributing to regime reproduction (or unsettling) operate across the boundaries of single jurisdictions. They exist in increasingly globalised networks of capital, knowledge, people, skills and resources. Multi-level and poly-centric governance imperatives are readily invoked in transition management, as they are in social-ecological systems research. An internationalisation of transition policy is considered by the Dutch government, for instance. But this is easier said than done. In recognising the necessity to operate across many jurisdictions, there emerges a considerable further challenge to transition

management, which is also relevant to scientific, business, civil society, as well as political, processes. Key nodes for influential intervention will be highly distributed, both spatially and temporally. How can transition arenas address the geography of socio-technical regimes?

So, whilst transition management proposes new governance arrangements informed by socio-technical transitions theory, it is unclear how these sit in relation to prevailing policy institutions and political processes. Transition management is not unique here, since other participatory approaches share this dilemma. However, given transition management ambitions to transform the structures of our everyday lives, this unclear relationship is especially problematic, because the basis for authority, legitimacy and accountability in transition governance will ultimately rest on the way it engages with other political processes and institutions.

Whose 'system' counts?

A key challenge for any approach as encompassing as socio-technical transition theory, is the bounding, partitioning and ordering of the system under consideration. Delineations between niches, regimes and landscapes can be unclear (Berkhout *et al*, 2005; Smith, 2007). The operationalising of key concepts can be ambiguous across empirical cases, including the periodising of transitions, from pre-development through to stabilisation (Genus and Coles, 2007). Of course, transition research is not unique in its sensitivity to analytical framings, but the high stakes, instrumental purpose and pressing timelines accentuate the implications.

These methodological challenges are amplified and become more overtly political when we move into multi-stakeholder transition arenas (Smith and Stirling, 2007; Walker and Shove, 2007). Different participants will carry their own mental model of the socio-technical system, its key components, major processes of development, their own position within the system, and favoured responses to opportunities for sustainable transformations (proactive or resistant strategies). Actors will appreciate a given socio-technical context in different ways – due to diverse contextual positions, contrasting knowledge or experience, and contending interests and purposes. Different groups will bring disparate framings of the 'system' both in terms of its structure and its function (Scoones *et al*, 2007).

Part of the purpose of transition governance is to negotiate these divergent framings, and attain a shared formulation of the system and commitment to a number of transition pathways. The question of 'who governs' gets re-emphasised, not simply for democratic reasons, but also because it has a material impact on the construction of the 'socio-technical system' in question (Smith and Stirling, 2007). This is a deeply political process (Berkhout *et al*, 2005). It demands an open reflexivity on the part of participants (including analysts – Stirling, 2006). It also requires transition management to be as attentive to the 'opening up' of alternative system framings and normativities, as to 'closing down' around a sub-set of pathways (Stirling, 2008a). This recursive dynamic necessarily involves mutually challenging engagements with broader political actors and discourses – and with the material interests that constitute the incumbent socio-technical system itself (Smith and Stirling, 2007).

Whose sustainability gets prioritised?

The political nature of this 'systems' boundary work is underscored when we consider the inherent ambiguity (and thus contestability) of sustainable development itself (Voss *et al*, 2007). The specific goals are often far from self-evident, seldom clear and susceptible to

highly variable orderings (Berkhout *et al*, 2005). There is typically ample scope for debate over the sustainability of both incumbent socio-technical regimes and alternative niches.

Sustainability appraisals and commitments are necessarily undertaken from different positions and perspectives. Headline goals for sustainability, such as carbon reduction, can command broad rhetorical consensus. More specific environmental, economic and social criteria, however, are hotly contested – with profound implications for the favoured pathways (like those towards carbon reduction). In the case of low carbon energy systems, for example, attitudes to radioactive waste, nuclear proliferation, landscape impact and biodiversity loss condition orderings of visions for nuclear, wind, tidal energy and biofuels. Even on those rare occasions where there is no significant scientific uncertainty over physical impacts, emissions or their consequences, there may typically be strong ambiguities over: the choice of indicators (Shove and Walker, 2007); the framing of metrics (Stirling, 1998); the setting of satisfactory levels of protection (EEA, 2002) and the relative weighting to place on different forms of harm (Dreyer and Renn, 2008). Such inherently normative matters cannot be decided by expert authority. This leaves crucial questions as to whose judgements should prevail? This applies also over time, where shifts in social values, interest perspectives and learning can reverse perceptions of hitherto favoured socio-technical pathways (Voss *et al*, 2007).

Of course, transition management is clear in encouraging reflexive and adaptable learning over uncertainties and the passage of time. Affinities with reflexive governance are cited (Voss and Kemp, 2006). However, this tends to focus on the micro-level modalities through which given visions are realised, not to pluralities or shifts in the visions themselves. In other words, little provision is made for processes of continual adjustment repeatedly to re-open debate over what is to be sustained, why, for whom, and how (Stirling, 2008a; Voss *et al*, 2006)? These concerns over the nature of sustainability underscore the queries raised earlier over 'whose system counts'. It is a key feature of transition management, that it represents the tense, vibrant, unbounded politics of sustainability as (as the name suggests) a matter for management.

Of course, many of the above criticisms are readily apparent to transition management advocates. Here, though, concerns tend to be interpreted as challenges requiring refinement to processes of engagement and negotiation within the framework, rather than necessitating fundamental reconceptualisations of how structural change originates and proceeds (e.g. class-based or counter-hegemonic perspectives in political economy). The point is not that transition management imposes some fixed, prior view of the socio-technical regime, sustainability goals, or desirable pathways. It is clear how these can be negotiated and realised through transition arenas. The point is that wider governance implications of technological transitions are necessarily more complex than an initial stage of negotiating closure around a particular vision of sustainability (and organising support for niche alternatives accordingly). The driving aims, orientations and modalities of sustainability itself, not just the managerial instrumentalities, are, in practice, much more plural – and continually open to radical reformulation. There is no shortage of sustainable socio-technical visions around which groups are mobilising in society, nor a lack of sustainable niche experimentation, whether corporatist or grassroots (Seyfang and Smith, 2007). Questions over the political conditions for the kinds of consensus and coordination implied by transition management, and how these conditions are to be achieved, have yet to be addressed fully.

Interlinked with – but even less tractable than – this, however, is the question of agency and power in (and over) incumbent socio-technical regimes. With notions of sustainability displaying such malleability to strategic interpretation, how credible is it that a transition

management process that begins within a vanguard of elite visionary forerunners, can really overturn structurally embedded regimes? How realistic is it to expect the obdurate infrastructures that form an important skeleton for these regimes to be responsive to the more challenging of the lessons generated in transition management? It cannot be assumed, that existing institutions and infrastructures will afford the requisite space and resources for the kinds of continual adaptations and social learning necessary for effective transition governance (Meadowcroft, 2005). Long-term decisions (such as which kinds of power station to invest in, or what forms of housing to provide, or transport infrastructure to develop), may be susceptible to future adaptation only around the edges. It might be possible to attend to 'future-proofing' and adaptation, but the typical picture in socio-technical regimes is one of obduracy. Whilst some of the above challenges can be addressed by 'doing transition management better', these questions of power and agency reinforce the complementary need for a broader – and more overtly political – project.

POWER AND AGENCY

A defining property of a socio-technical regime is the interdependent, highly institutionalised alignments across heterogeneous processes that serve to reproduce the regime, and which tend to engender path-dependent development. This constitutes a form of structural power which privileges certain actors at the expense of others. Transition management has to consider how to engage with these power relations in order to realise the transitions it envisages and boost the development of promising niches. The conclusion is, that much in transition management requires levels of co-operation, collaboration and consensus-building that can prove very difficult to attain. How is this to be achieved?

Geels and Schot (2007) suggest socio-technical niches and regimes are 'organisational fields' – communities of interacting groups – with regimes more stable and larger in this respect than niches. Each requires regulative, normative and cognitive rules in order to help coordinate action. Following Giddens' structuration theory, it is suggested that socio-technical rule sets are constantly maintained and re-made through the interacting socio-technical practices of actors in regimes and niches (Geels and Schot, 2007). Significantly, rules do not solely constrain but also enable actors to participate in socio-technical system development. Transition management has to engage and modify these rule formation and reproduction processes. However, as pointed out earlier, long-lived, material infrastructures, that are important embodiments of earlier rule sets, dampen, delay and raise the stakes of attempts at rule reformulation.

Smith *et al* (2005) suggest power and agency be analysed through an examination of the membership of socio-technical regimes, resource interdependencies between actors, and the expectations about future developments in prevailing discourse about socio-technical practices. Some regime members are more powerfully situated than others, in the sense that they command key positions in the reproduction of incumbent regimes. They enjoy privileges associated with an ability to mediate and influence ongoing socio-technical changes. Structural power derives from this contribution to maintaining the rules, infrastructures and values underpinning socio-technical practices. But this position is not assured.

Power and agency are not as straightforward as might at first appear. The investment decisions of an infrastructure business (like an energy utility), and those of its regulator, are

both significant for the continuing development of the socio-technical regime which the infrastructure supports. However, the regime is also effectively reproduced by the millions of routine, small decisions taken (often invisibly) by end users. The ways they respond to any changes will add up to an emerging development of the regime that can be difficult to anticipate precisely (Shove and Walker, 2007). Whilst the utility company clearly has the capacity to introduce greater changes than everyday users, the responses of the latter complicate the ability of the former to anticipate outcomes arising from the changes they instigate.

The resources needed to induce significant socio-technical change are distributed across different actors (i.e. the material, cognitive, political, economic and institutional resources needed to re-write the rule sets). This distribution obviously includes regime membership; but it can involve resources in actor networks beyond the regime (e.g. knowledge about alternatives amongst niche participants; legitimacy issues deriving from social movements). The meaning and value of different resources in regime reproduction, or transformation, alters over time, due to broader, contextual developments in the landscape. Interdependencies between actors shift. Power relations alter. New discourses generate new expectations about the adequacy of regime performance (such as its sustainability) and contribute to a re-ordering of priorities. The status of resources and regime position of different actors are cast in a new light. Socio-technical regime developments and transformations are an emergent outcome of resource-interdependent actors negotiating material responses to future expectations in a context in which some are structurally privileged by their position within the incumbent socio-technical regime.

Structural change in something as pervasive as a socio-technical regime entails many losers as well as winners. In considering what a transition to sustainability actually means, the stakes are typically very high (Meadowcroft, 2005). Targeted socio-technical interventions carry implications for the kinds of technologies, social practices, institutional forms, policies, plans and innovations that become valued in transition experiments, and subsequently attain a marketable and political significance, and those that do not. The way the socio-technical regime is characterised and problematised and the diversity of pathways and experiments supported (what gets written into and out of transition management) has distributional consequences.

Inevitably, regime incumbents have to become involved in socio-technical transitions, since they occupy a critical position in regime reproduction and change, and they often occupy influential positions in the existing policy networks and discourses that contribute to the governance of the regime. This is the pragmatic position. However, the fear is that, in the absence of a sufficiently powerful countervailing constituency seeking changes more radical than the incumbents find comfortable, then the transition management process risks capture by incumbents (Smith and Kern, 2007).

Of course, one important source of countervailing pressures that can provide a supportive power base for transition management lies in favourable 'events' occuring within the broader landscape. These can involve the mass mobilisation of a social movement demanding greater sustainability. Or they can arise from a series of environmental or economic crises that bestow greater credibility on the more radical arguments within a transition arena. These and other processes can put the incumbent membership, institutions and material infrastructures of the socio-technical regime under considerable pressure to undertake more radical change than they might be otherwise inclined to do. At these moments, the interdependencies that made the regime so enduring can become problematic, since they constrain responses to these significant new pressures. The regime may become fragile, even susceptible to collapse. This prompts wider searches for solutions, and it is in this light

that transition management may be able to build a powerful base for support. However, this is beyond the agency of those engaged in the transition arena itself. Rather, it requires the arena to develop a political capacity for positioning itself favourably in the light of ongoing processes, mobilising support, influencing agendas, and re-directing investments and other commitments away from incremental repair work, and towards more radical transition goals.

SOCIO-TECHNICAL AND SOCIAL-ECOLOGICAL RESILIENCE

Socio-technical regimes are structures for movement of materials, energy, people, information, goods, services and money; which are increasingly global. They implicate many different social-ecological systems. How can the social-ecological systems resilience of a fossil-fuelled electricity socio-technical regime best be governed when the components and connections are so distributed in space and time? Each distributed element typically impacts in diverse loci on different social-ecological systems. The success of socio-technical and social-ecological system governance processes are clearly linked, but this accentuates the complexity and uncertainty of the interactions. Social-ecological systems resilience in one place and time can depend on interventions to alter socio-technical regimes at entirely different places and times. Under such circumstances, it becomes necessary to resolve a variety of different spatial, temporal and systemic nuances that are presently conflated in conventional notions of 'resilience' (Stirling, 2008). In particular, socio-technical regimes may exhibit resilience towards pressures for transitions, such that they undermine the resilience of the social-ecological systems that they effect.

Under a social-ecological systems perspective, the interest lies in the material resources and services implicated in the development and operation of the technology. A key question, is how resilient is that relationship for the social-ecological system? Socio-technical regimes are dynamic, in the sense that there are always changes creating re-adjustments. But these tend to be along path-dependent trajectories. Interestingly, this momentum and path-dependency in regime trajectories may themselves be seen as a form of resilience. The ways socio-technical regimes continue to provide valued social functions against a background of landscape developments, internal contradictions, and competitive niche pressures, constitute a form of socio-technical resilience that, in some instances, undermines social-ecological system resilience.

Considerable investment and repair work goes into maintaining and enhancing the performance of socio-technical regimes (e.g. infrastructure maintenance, training skilled personnel, marketing the benefits to users, regulatory institutions). However, some of the most significant socio-technical regimes associated with modernity (such as centralised water systems, or fossil fuel electricity systems), are experiencing considerable stress. They can look quite fragile in the face of environmental changes like drought and resource constraints. Repair work seeks incremental adjustments to the regime in response to these pressures, e.g. building new water reservoirs, research into carbon capture and storage, liquid transport fuels from coal. These attempts to enhance resilience for incumbent regimes influence the resilience of associated social-ecological systems. Socio-technical 'resilience' – (the dynamic persistence of a regime under episodic shocks) or 'robustness' (system maintenance under cumulative stress) – can be predicated on forms of continuing environmental degradation that harm social-ecological system resilience (Stirling, 2008; forthcoming).

Governance for social-ecological system resilience has to attend to the governance of socio-technical regimes. However, dialogue between these two disparate domains of activity has to keep in mind the contrasting objects and objectives for governance in the two areas. Social-ecological systems research takes a social-ecological system as its basic unit of analysis. It is interested in all the endogenous and exogenous processes that influence its state and – depending on the desirability of that state – how to improve its resilience or transform to an alternate, more desirable system state (Walker *et al*, 2006). As noted in Figure 1, technology contributes endogenously and exogenously to the process, but is not central and (as mentioned above), is rarely unpacked and considered dynamically.

Socio-technical research, in contrast, holds the technological and social practices that satisfy (and help constitute) human needs at the centre of its analysis. It is interested in the niche, regime and landscape processes that influence the development trajectories of incumbent socio-technical regimes, and how governance can harness and modulate those processes in order to shift development towards more sustainable socio-technical practices. The fate of social-ecological systems is a concern within this quest for sustainable regimes. This can be expressed, for example, in the pursuit of water- and energy-efficient housing regimes in order to reduce pressure on wetland habitats, and reduce carbon emissions that impact more pervasively upon many social-ecological systems. However, social-ecological processes are not integrated centrally into transition studies.

Instead, nominally more sustainable socio-technical niches are analysed and explanations for their (lack of) development provided. Niches like biogas, organic food, and electric vehicles are studied as alternative practices to incumbent counterparts in energy, food and mobility regimes. This research is helpful because it explains how and why different niches succeed or struggle (Raven, 2004; Smith, 2007; Hoogma *et al*, 2002). But this is different to considering how, where, and why these diverse greener socio-technical practices contribute to enhanced social-ecological system resilience.

Risk, cost-benefit, life-cycle, and environmental impact analysis of niche socio-technical practices can provide relevant information. But these typically beg questions over uncertainties and contending framings of technological trajectories, contextual conditions and the striking of acceptable balances between benefits and harms (Stirling, 1998). Nor do such approaches yet typically address the dynamic considerations of social-ecological system resilience. As we saw, sustainability goals are inevitably ambivalent, and the socio-technical visions and transition pathways always tentative and provisional. Nevertheless, these appraisal processes tend to be driven (like transition management) by particular contingently-framed criteria of welfare, risk or sustainability, attending mainly to the options for delivering on these.

For its part, the social-ecological systems literature considers resilience as the ability to maintain system structure and function in the light of both shocks and stresses in the wider environment (Berkes *et al*, 2003). The socio-technical systems perspective poses a number of questions regarding these terms. There are queries over the difference between episodic shocks and secular stresses mentioned above, for instance (Stirling, 2008b; forthcoming). Beyond this, there are questions over the distinction between system structures and functions. In technological (more than ecological) systems, the point is often precisely that the former militates *against* the latter. Questions therefore arise as to whether the object of resilience is structure or function (Stirling, 2008b). In these terms, the aim of transition management is to achieve structural (socio-technical) transformations that improve performance in the desired sustainability functions. The aim is thus resilience with respect to these functions and those socio-technical structures that are judged best to deliver them – and emphatically not with the countervailing incumbent structures themselves.

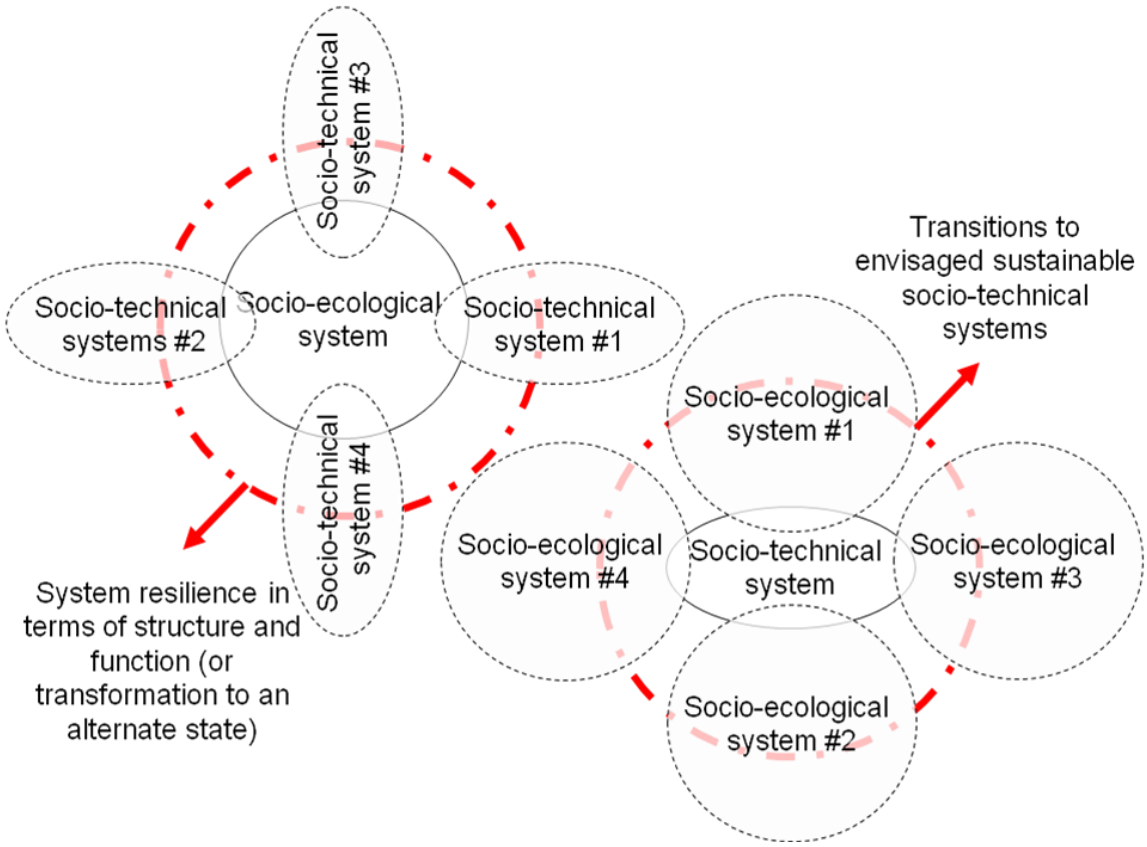
As we have seen, incumbent socio-technical regimes are, by definition, structurally resilient. When regimes are no longer able to withstand shocks and stresses (e.g. landscape pressures in the socio-technical transitions terminology), then they become destabilised, decline and susceptible to transformation, i.e. they are no longer regime-like. This dynamic property of resilience – as a capacity to resist both shocks and stresses – is (in abstract system terms) highly congruent as between social-ecological and socio-technical systems. Yet the formal correspondence breaks down where structural socio-technical resilience militates against delivery of sustainability functions (e.g. fossil fuels and sustainable energy services). Here, the governance challenge is to erode the structural resilience of incumbent socio-technical regimes in order to promote social-ecological systems resilience. At the same time, if alternative, more sustainable, socio-technical structures are to emerge successfully from niches and develop as regimes (and influence landscapes) then these must acquire high levels of structural – as well as functional – resilience. In practice, the bases, forms and extent of structural and functional resilience, and relations between them, is an empirical question relating to the system under consideration.

In sum, social-ecological systems research and socio-technical research hold different aims. Both grapple with complex adaptive systems and are concerned about sustainability. As such, general orientations towards social learning, flexibility, and reflexivity involve them in common concerns. However, at heart, they are trying to do more specifically different things. Social-ecological systems research (no matter how sophisticated its treatment of interacting scales and levels) is concerned about the services flowing from a social-ecological system rooted in a particular spatial context. All the case studies reflect this point of departure (e.g. a watershed, a rangeland, a forest, a region).

Socio-technical research is not so place-bound. It is concerned with socio-technical practices within a regime that operate simultaneously across multiple (often quite unconnected) loci. Regimes span social-ecological systems, and developments can mean they implicate different social-ecological systems over time. Consider, for example, the automobility socio-technical regime constituted by cars, road infrastructures, fuel supply networks, and private transportation institutions and culture. The way sustainability concerns are prompting some firms and motorists to explore switches from fossil fuels to biofuels and hydrogen (generated from chemically processing fossil-fuel, from nuclear or renewable electricity) will implicate different patchworks of social-ecological systems in resource extraction and waste assimilation.

Figure 2 illustrates the above distinction schematically. None of this invalidates translation of insights and lessons between the literatures, but it does remind us to do so with care. This includes the translation of challenges and criticisms in the respective literatures – including our own cautionary words based on criticisms of transition management. We contend that challenges about who governs, whose system framings count, and whose sustainability gets prioritised *are* pertinent to social-ecological systems research. They suggest an agenda that explores critically the kinds of structural and functional resilience that are helpful or unhelpful, and for whom, and with what social purposes in mind.

Figure 2: a schematic representation of differences and overlaps in the analysis and governance of social-ecological systems and socio-technical systems



Given our focus on technology, the main perspective adopted here is grounded in the socio-technical systems literature. It is from this vantage point that we look out for bridges and overlaps with social-ecological systems research. This complementary focus may be justified by observing that it is technology that mediates social-ecological relationships at many levels:[4] shaping our understandings of social-ecological systems as well as constraining and enabling possible actions. Technology thus lies at the heart of policy challenges in impact abatement, resource efficiency and ecological resilience. Though environmental aspects are still typically only poorly considered in the general socio-technical systems literature, the governance implications remain highly relevant for social-ecological systems research. Indeed, it is similarities between the governance prescriptions in the two literatures that are prompting dialogue (van de Brugge *et al*, 2007; Foxon *et al*, 2008). This article suggests this dialogue has to be open to criticisms in the respective literatures also. It is in this quite particular and conditional way, that some of the critical challenges confronting transition management will remain valid for adaptive management.

[4] Though not exclusively. Institutions are also powerful mediators; as are prevailing discourses on social-ecological relationships. And each exerts influence upon the other.

CONCLUSIONS

Our discussion has been quite wide-ranging. We introduced the roles that technologies play in shaping social-ecological systems and affecting their resilience. The interdependencies that provide socio-technical regimes with their momentum were re-considered as a form of resilience that is quite directly congruent with this same formal dynamic property in social-ecological systems. Yet the contrasting normative and substantive context of technology means that the implications of resilience may contrast strongly between these areas. In particular, we have to reflect on what precisely it is that is being made resilient, in the face of which specific dynamics, for whom (and by what criteria) this is good or bad, and whether such resilience is consequently problematic or not.

Transition management seeks to transform socio-technical regimes into more sustainable forms. However, this challenge has not hitherto been considered from a resilience perspective. How do we create socio-technical regimes that are socially and environmentally resilient? And how do we ensure this resilience is not predicated on displacing problems elsewhere? The biofuel controversy is one example of how a misguided attempt to bolster the sustainability of mobility regimes through novel transport fuels can undermine social-ecological system resilience at different sites. Can governance initiatives guide the innovation of biofuels that are less destructive of social-ecological system resilience?

Particularly instructive has been the critical challenges facing transition management regarding the social construction of the 'systems' to be governed. The recognition that drawing boundaries and understanding system structures, functions and processes is far from self-evident begs questions about whose system counts. The negotiation of social-ecological systems must confront similar normative, epistemic and ontological challenges.

This in turn raised questions about participation, legitimacy, and democratic accountability of governance initiatives. How should these problem-focused, adaptive and reflexive governance activities link to the more general-purpose and formal institutions of political authority? Even more challenging is how these bottom-up governance initiatives confront the deeply-structural forms of power vested in the socio-technical regimes that the transition arenas wish to transform. To the extent that these regimes impinge on specific social-ecological systems, then the adaptive governance of the latter will also have to confront the structures of the former.

The complexity and contingency of these challenges can appear alarming from the more managerial end of the governance spectrum. Dismay can turn to despair when the complex geographies and jurisdictions of links between socio-technical systems and social-ecological systems are considered. However, a more politically-inclined perspective sees hope in the messiness and slipperiness of processes beyond the reach of the more managerial forms of transition management. Reflexive governance of a sort is already practised on a day-to-day basis by the social groups and movements who lobby to get their social-ecological priorities heard by political authority and economic power, and who create alternative niches offering inspiring solutions for others to adopt and adapt. They contribute pressures that constantly interrogate particular framings of socio-technical regimes, and transition policy, and which re-opens them for debate.

This final observation suggests additional lines of research and action beyond developing ideal governance processes and arenas, and arguing for their adoption. One addition is more reflexively to understand the conditions and perspectives under which this kind of governance might become adopted. How fruitful this endeavour would be is open to question, since it too will involve political transformations beyond the agency of transition managers. However, we would suggest another addition based on our observations above. This is to recognise that the wider politics of sustainability already exercise a form of reflexive governance (however imperfectly) by challenging governance appraisals and commitments, and introducing pressure to reflect over, and 'open up', the ways that current socio-technical and social-ecological systems are governed. Transitions analysis can thus be considered as a means to provide heuristics and tools for multiple contending actors (businesses, government and civil society) to intensify and enhance their engagements towards the definition (as well as pursuit) of more sustainable socio-technical and social-ecological systems alike.

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